National Estuarine Research Reserve System

Kachemak Bay Research Reserve
www.kbayrr.org

# THE ROLE OF ESTUARINE HYDRODYNAMICS IN THE DISTRIBUTION OF KELP FORESTS IN KACHEMAK BAY, ALASKA*

by Steve Baird, G. Carl Schoch** and Heloise Chenelot

## ABSTRACT

Kelp forests are complex three-dimensional habitats supporting tightly linked trophic interactions between primary producers (kelp), herbivores (sea urchins), and carnivores (sea otters). Therefore the spatial distribution and the variability in size and density of this important habitat can affect local food webs. Kelp forests were mapped from 2000 to 2002 using low altitude aerial photography to produce oblique digital imagery. These images were geometrically corrected and the kelp beds delineated. Density estimates were made for each polygon. The polygon data were entered into a GIS so that estimates of areal extent, density, and adjacency could be compared among beds and among years. The mean kelp forest area during the study period was 25.9 km² with a variance of about 15% in surface area among years. This variance was mostly due to the inundation of rocky kelp habitat by sand. A 4 km depositional spit separates Kachemak Bay into an inner and outer basin. Evidence suggests that strong estuarine circulation prevents kelp dispersal into the inner bay and the cyclonic surface circulation forces the spatial distribution in the outer bay. The distribution of kelp forests in Kachemak Bay is therefore apparently linked to sediment transport dynamics and oceanographic circulation patterns.

## METHODS


*Fig. 1. Low altitude aerial images were obtained in Kachemak Bay (A) late in the summer when plant growth was near maximum but before winter storms damaged the kelp forests (B). Images were acquired with a Hasselblad 501CM camera from a Cessna Bird Dog when the tide level was below MLLW and the sun angle was near zenith. These images were individually rectified to digital orthophoto quadrangles. Each kelp bed was delineated by a polygon and incorporated into a GIS vector data layer (C).*

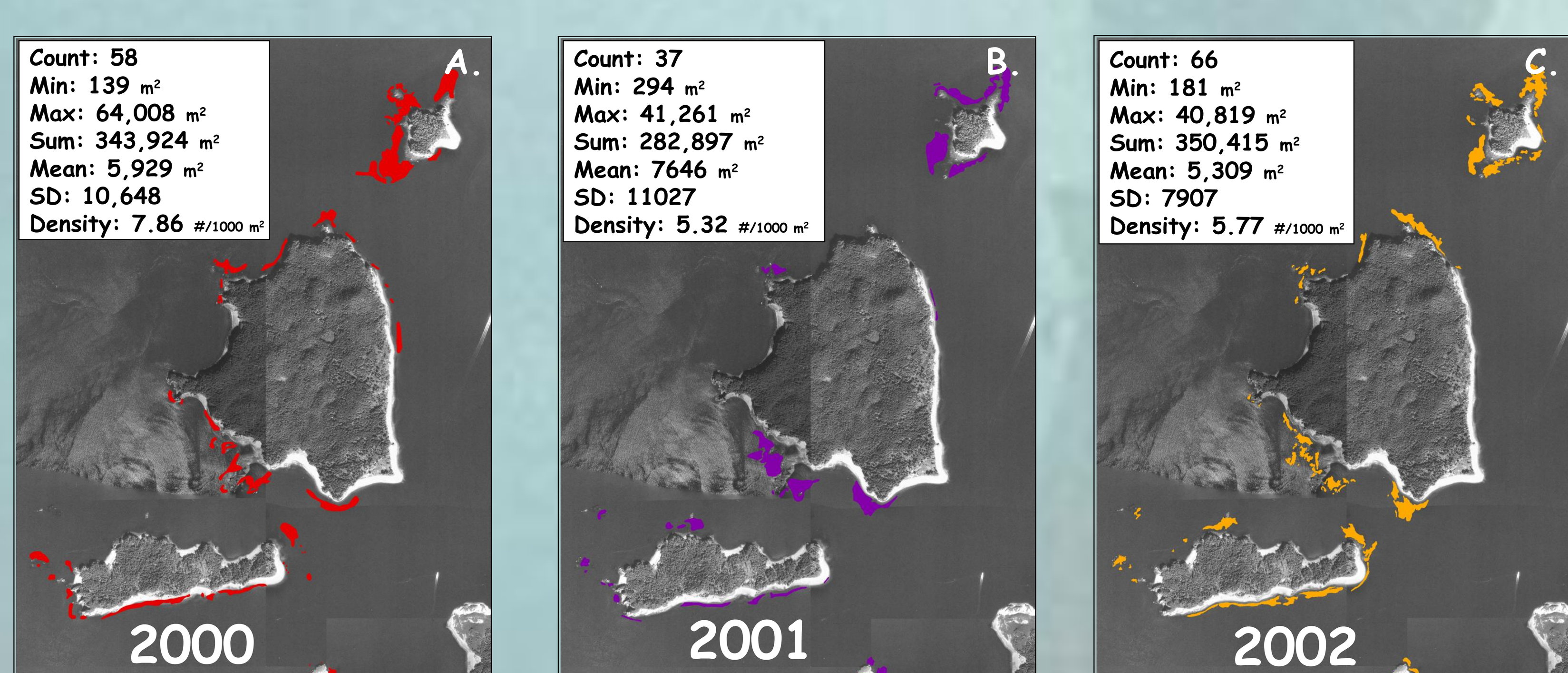


*Fig. 2. Polygon vector layers representing the annual spatial distribution and areal extent of all the kelp beds in Kachemak Bay were assessed for among years differences (A-C). At small spatial scales (10's meters) kelp beds fluctuated in size and density from year to year and in some cases the kelp beds did not reappear in the same place. At larger scales (100's meters), kelp beds were found consistently during the three year study but the total area and densities were significantly different. Subtidal transects on the south side of the bay showed no evidence of change in the bottom habitat which is predominantly large boulders with interstitial cobbles. The predominant herbivores on the south shore of Kachemak Bay are the snails Lacuna vincta and Margarites pupillus, but on the north shore the green sea urchin Strongylocentrotus drobachiensis is more abundant.*

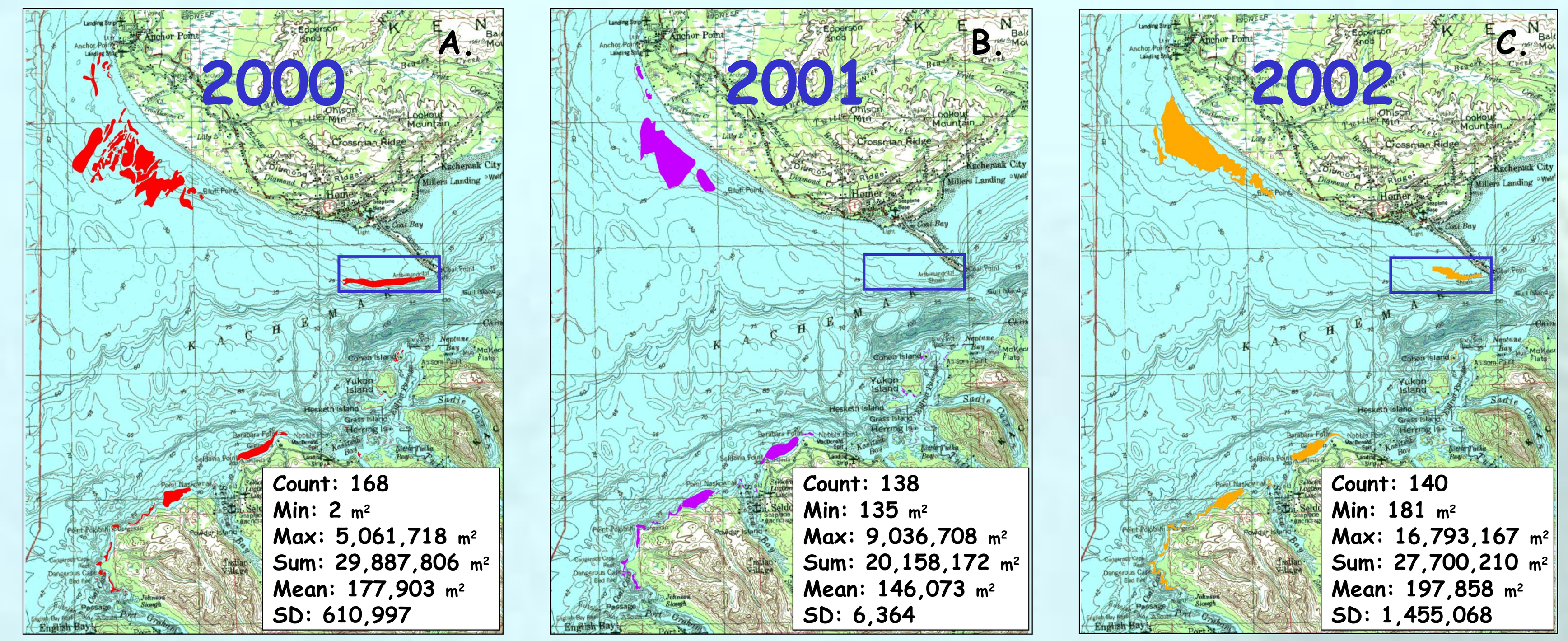


*Fig. 3. Significant differences were also found among years in the largest kelp forests on the north side of the bay (A-C). The north shore kelp forests are a mixture of Nereocystis luetkeana and Alaria fistulosa. They are large because the local bathymetry is relatively shallow compared to the steeply sloping south shore. The south side kelp forests are predominantly Nereocystis luetkeana. Note the absence of the 4 km long kelp bed near the town of Homer (boxed) and the changes in shape and extent of the kelp beds near the villages of Anchor Point and Seldovia between 2000 (A), and 2001 (B). The kelp bed off the town of Homer returned in 2002 (C) but with a lower density than in 2000. The annual fate of this kelp bed was found to be associated with habitat modification by sand waves transported from eroded bluffs between Anchor Point (top left of image) and Homer.*

## Hypothesis 1: the spatial distribution of kelp is limited by estuarine water quality

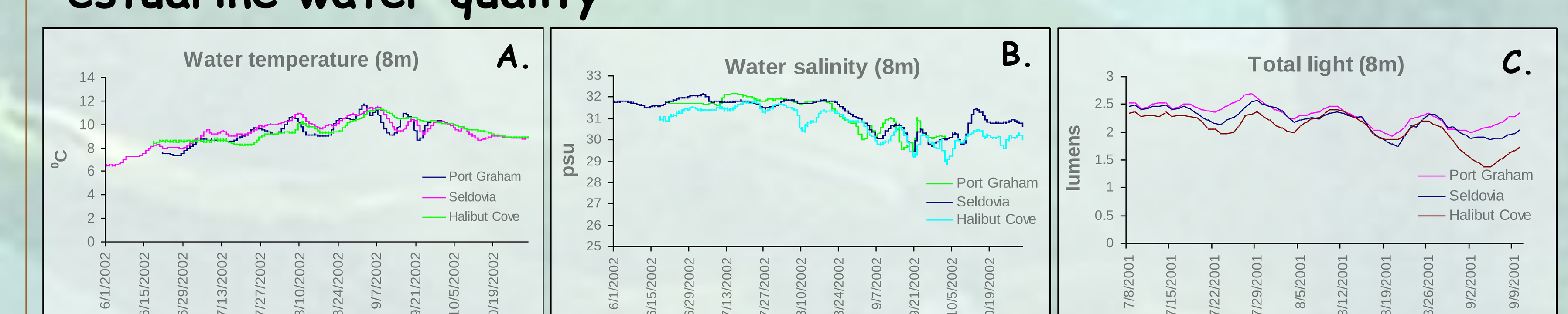


*Fig. 4. Water quality sensors were established to measure water temperature (A), salinity (B), and light (C) at three sites along the axis of Kachemak Bay: near the mouth of the bay where there is the most marine influence (Port Graham: PG), near the estuarine front where there is the most mixing (Seldovia: SE), and well inside the Bay where conditions are the most estuarine and water column stratification is well developed (Halibut Cove: HC).*

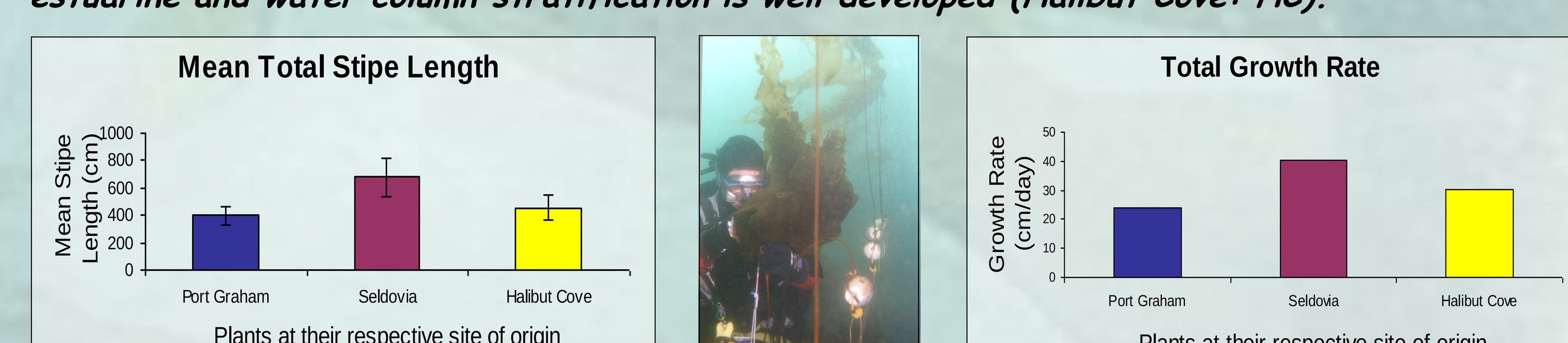


*Fig. 5. Reciprocal transplant experiments were established in kelp beds adjacent to each of the three instrumented sites to measure the effect of water temperature, salinity, and light penetration on growth rate. Since the kelp beds at PG are in more marine conditions and usually appear the earliest in the year relative to kelp beds at SE and HC, we hypothesized that the growth rate at PG would be higher than at the more turbid and lower salinity sites at SE and HC. But the total stipe length at the end of the summer was the longest at SE and the shortest at PG. The growth rate was also higher at SE than at either PG or HC. However, snail herbivory was highest at SE and these plants also suffered the highest mortality. These results suggested that the low salinity, high turbidity water at HC was no worse for plant growth rate than the more saline, higher light environment at PG. An alternative hypothesis (of no habitat availability) was also rejected since many rocky reefs occur in the inner bay, but all are devoid of Nereocystis luetkeana.*

## Hypothesis 2: the spatial distribution of kelp is limited by spore dispersal

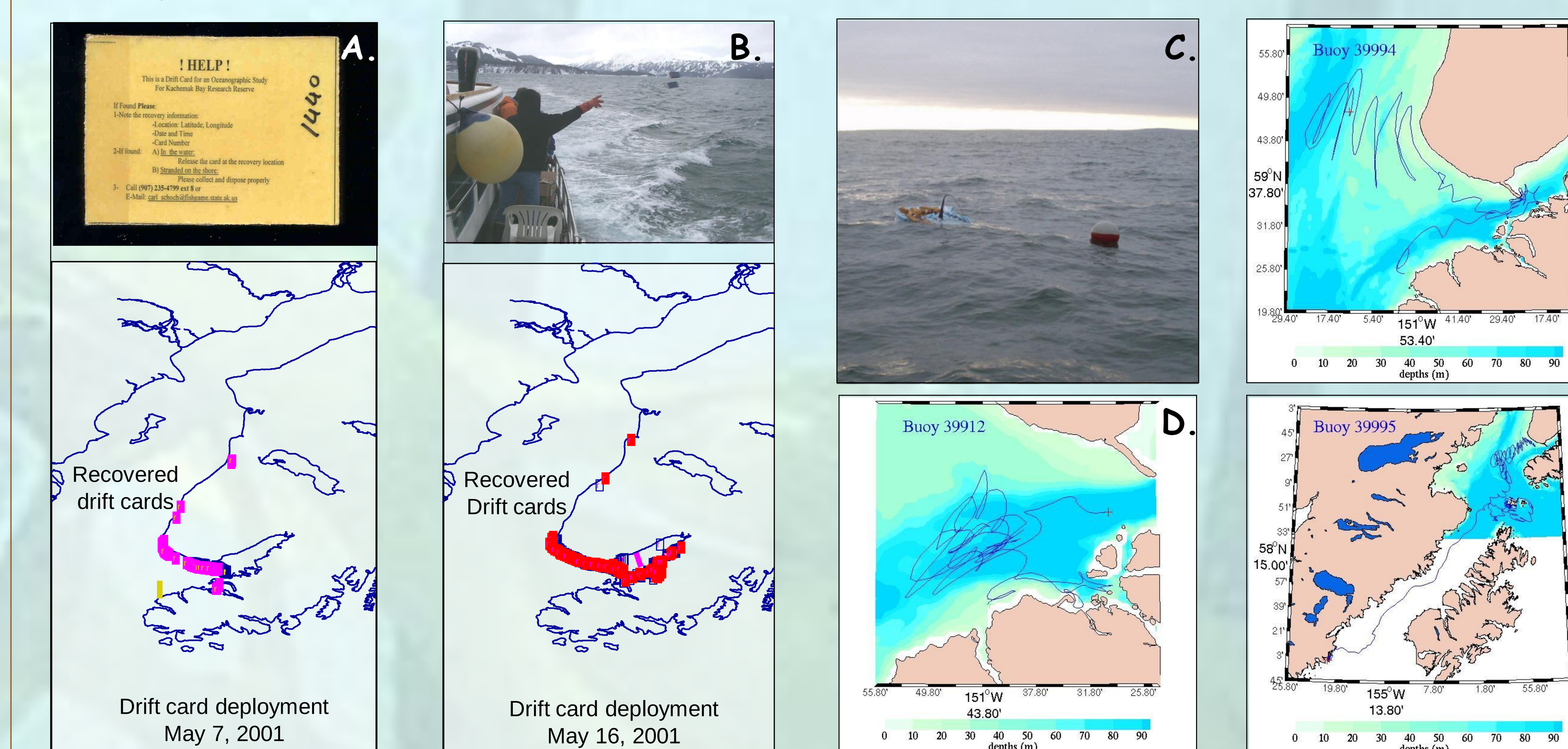


*Fig. 6. Drift cards were initially used as a low-cost means to study surface currents. Over 10,000 cards were deployed in Kachemak Bay at different locations and seasons. Drift cards deployed from the outer bay were not transported into the inner bay in either summer or winter (A). About 85% of the drift cards deployed from the inner bay were advected out of the bay (B). This work was followed by a study that deployed drogued drifters in the outer bay (C). All of these were transported out of Kachemak Bay suggesting that there is little local retention (D, E, F).*

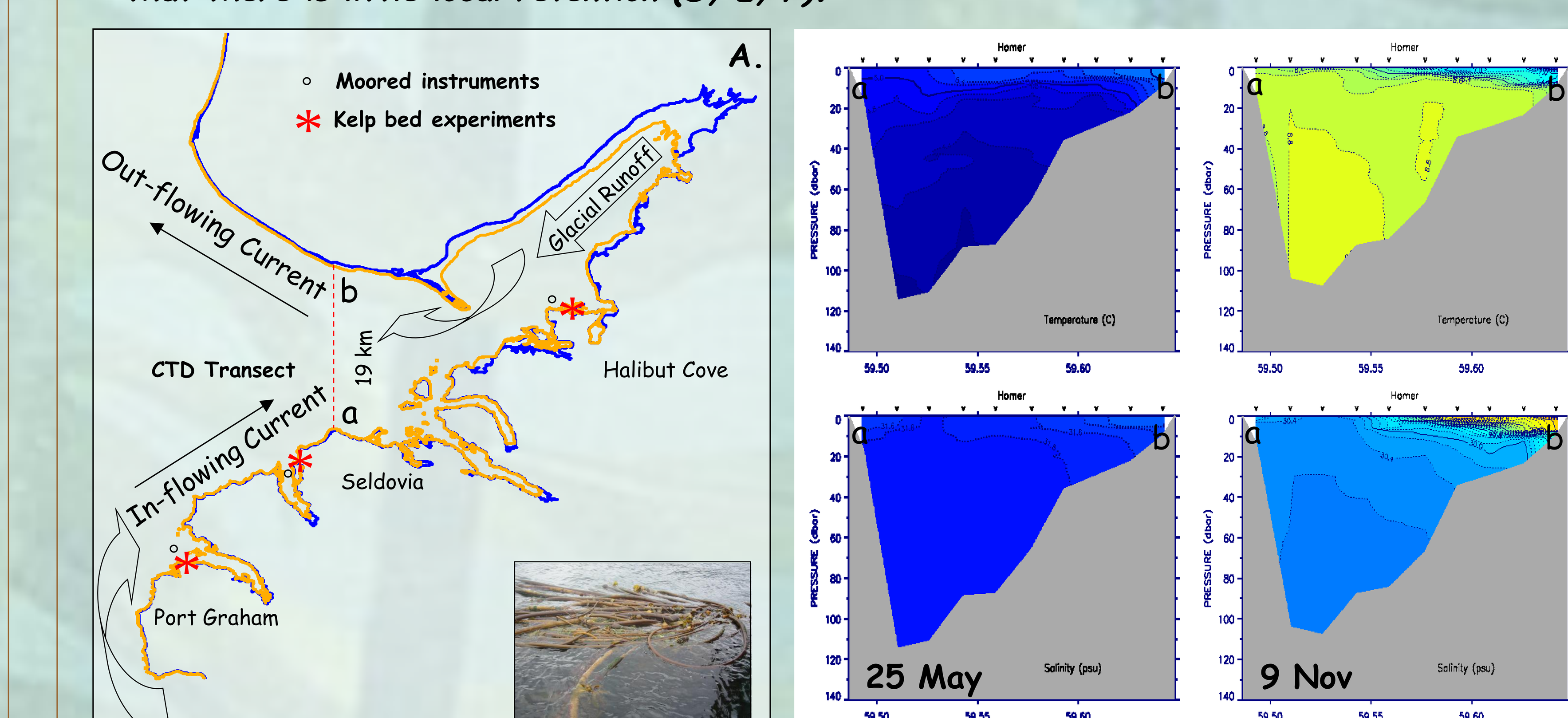


*Fig. 7. The circulation of water in Kachemak Bay is complex and reflects the combined influences of diurnal and monthly lunar inequalities in tidal forcing, seasonal changes in the tidal regime, meteorological effects and fresh water forcing (A). The results of the drifter studies suggest that the surface circulation into the inner bay, and the trajectory of floating kelp rafts dispersing spores (inset), may be limited by the seasonal density driven current flowing out of the bay (B).*

## SUMMARY OF RESULTS

This study provides evidence that the spatial distribution of kelp beds in Kachemak Bay is forced by the circulation patterns causing surface water to be deflected from the inner bay and transported in a cyclonic gyre along shorelines of the outer bay. Kelp plants mature at this latitude late in the summer or early fall coinciding with the intensification of winter storm systems. Many of the large sporophytes cannot withstand the drag imposed by higher waves and break free from their holdfasts. Spores are thus dispersed over great distances when large rafts of free-floating sporophytes are carried by the prevailing circulation pattern around the outer bay.

* Partially funded by the National Fish and Wildlife Foundation, CTD data was provided by Steve Okkonen, drifter data provided by Mark Johnson, University of Alaska Fairbanks, ** Contact: carl_schoch@fishgame.state.ak.us